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SCIENCE & TECHNOLOGY IN THE SOVIET UNION

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—KARL MARX *in his address to the International Working Men's Association.*

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SCIENCE AND TECHNOLOGY IN THE SOVIET UNION

PREFACE

By R. Page Arnot

THE chapters of this book were originally delivered as papers at a Symposium on "Science and Technology in the Soviet Union," arranged by the Science Faculty of the Marx Memorial Library and Workers' School. The themes selected are such as would promote a closer understanding between men of science in Great Britain and in the Soviet Union. But the aim was wider, as was implicitly acknowledged by the B.B.C. in the publicity they gave to the Symposium, than any routine exchange of information between specialists. The aim was to strengthen collaboration between the freedom-loving peoples by making public achievements hitherto largely unknown and to enable the example of Soviet men of Science to be emulated in this and other countries of the United Nations.

Nor is it only the achievements that are recorded in this book but the problems and methods of Soviet science and technology. Those who have marvelled at the power and resistance of the Red Army and of Soviet economy in contrast to what is remembered of Tsarist Russia may here find a part of the explanation. They will find that science and technology receive greater attention than has hitherto been paid to them in this country and that the life of the people is bound up with the advancement of science and cultural development. To those who would seek further explanation than can appear in these pages I give a hint that their research might be directed to the work of Lenin, whom his great disciple Stalin described in a speech as

> "a model of a man of science boldly challenging science gone obsolete and blazing the trail for new science."

In the same speech, made in 1938, Stalin called a toast to the flourishing of science; "of such science as does not segregate itself from the people," and then went on to say:—

> "To the flourishing of science! Of such science as does not let its old and recognised leaders smugly retire into their shells as pontiffs of science, as monopolists of science; of the science which appreciates the meaning, significance and omnipotence of the union of the old scientists with the young scientists; which voluntarily and willingly throws open all its gates to the youthful forces of our country, offering them the opportunity to conquer the peaks of science; which recognizes that the future belongs to the youth of science.
>
> "To the flourishing of science! Of such science whose devotees, whilst realizing the force and significance of the traditions established in science and making skilful use of them in the interests of science, yet refuses to be slaves to these traditions; of science, which has the daring and determination to shatter old traditions, standards and methods when they become obsolete, when they turn into a brake on progress, and which is able to establish new traditions, new standards, new methods."

Words worth pondering, perhaps especially in Britain.

It was to the men of science who have developed under such a leadership that the Easter Symposium sent the resolution of greetings printed on another page. May all who read this book join in that greeting and in the pledge with which it ends, of "greater efforts in achieving speedy victory."

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PHYSICAL SCIENCE IN THE U.S.S.R.

By Professor J. D. Bernal, F.R.S.

I am not going to claim to give an exact picture of present work on physical science in the U.S.S.R. I would very much like to do that, but two circumstances effectively prevent me—one is that owing to the war, it has been extremely difficult to get any comprehensive picture of the work and secondly, that my own occupation has prevented me from following what publications have come out in the U.S.S.R. or read them with the care they deserve. What I hope to do in connection with the physical sciences is to give you some idea of the background that lies behind the particular applications discussed in the rest of the session. One might get the impression—an impression which is rather favoured by some of our most academic scientists here—that science in the Soviet Union differs from science in the capitalist countries by its concentration on immediate and practical results. Now it should, I think, be fairly clear to any who are scientists, that it is in fact, quite impossible to achieve any applications of science of value unless they are based on sound and progressive fundamental work, and the fact that we hear more about the application and less about the fundamental work is simply because the general public is more concerned with the kind of things that affect their lives. The fundamental part of science is, as Professor Haldane has stated, just part of the general body of science which is not in any way specifically Soviet. Now, from what has been done in the way of successful application, one can see that there has been in the Soviet Union an immense development in the study of fundamental physics and chemistry.

I think people should realise the extent of that from the extremely small nucleus started with. At the beginning of the new period, say about 1920, there were in the Soviet Union about forty trained physicists. And these forty trained physicists had the job of building a growing school of physics research and education as well as directing researches on the physical aspects underlying the rapid development of Soviet industry. Now that was a job which had to be undertaken at once and which put an immense strain on the intellectual reserves of the Soviet Union, but by providing a planned development of education, research and application, they have built an enormous edifice of physical science, an edifice which is showing its worth in the present war and which is continually growing.

I had the experience a very long time ago, in 1934, of living and working with the Soviet physicists and particularly paid attention to what they were doing in the way of training new physicists. The early training was, of course, of a heroic kind. The kind of training that people got between 1920 and 1930 was a training in the midst of Civil War and the new economic policy, and the violent first stages of the Five-year Plan. But by that time enough of the first group of teachers were trained to settle down to a series of systematic training of students. In Leningrad, for instance, in the big polytechnic institute, there was a six-years' course which was far more thorough and more rigorous than that I was accustomed to in Cambridge. This physics course included as its standard work elements which

would be considered a special research in other countries, such as sealed off high-vacuum work and constructing various types of very complicated radio apparatus. As a result of this long-term policy it was only in the year 1934 that the first fully trained physicists were being turned out. But it was well worth it. From that year onwards increasing numbers of fully trained physicists graduated. I wish I could give you the total number of trained physicists in the Soviet Union to-day, it must run into tens of thousands. There were ten thousand when I was there ten years ago.

It is to this body of young trained scientists we must look for the real strength of Soviet science in the present war and in the future. It is a mistake to judge science in a country by its immediate products without taking into account its historical development. Soviet Science has had to put up with the same shortsighted criticism that attacked every aspect of the Soviet State. From about 1930 to 1938 well intentioned people were asking why did not the Soviet Union improve the life of the people more rapidly than it was doing instead of building large factories and setting up heavy industries. Why did they not concentrate on the immediate production of good things instead of putting people through the hard school of work and want. The answer to that criticism is now apparent to everybody. It is that in the Soviet Union, unlike the rest of the world, there was a rational thought-out plan which took into account the realities of the situation. They knew from 1917 onwards that no country which had not got a solid industrial basis and a people thoroughly trained and hardened in the use of their industry could withstand the stresses that would certainly come in the period of war which was clearly foreseen.

In this country, to a large extent, in fact in every country in the world, there was a feeling that science and art could be developed for their own sakes. We have produced in this way some of the finest works of physical science that have been seen in the whole world. But that was a kind of specialism which lacked a solid basis, and the lack of that solid basis—trained physicists and an understanding attitude towards physics on the part of the population as a whole—is painfully evident to-day. We are woefully short both in the supply and services of trained physicists. That we have not got among the population at large that appreciation of the principles of science, enabling us to use what physics we have to full advantage—is shown clearly in the war. All that is quite different in the Soviet Union, which has tens of thousands of trained physicists. Their general education produces an appreciation of physics which enables the soldier or industrial worker to see what the physical implication of his work is and how to improve it.

The picture of science in the Soviet Union has a different balance than ours. The basis of the physical sciences lie in Soviet heavy industry: electrical industry, metal industry and chemical industry, and on that basis rest field laboratories, technical institutes and finally the whole Academy. The whole is tied together in an organised way that we are only beginning to appreciate, it is a way for which all the serious leaders of physics in this country are pressing at this moment. There is close contact of the physicists in the laboratory and the worker in industry. What that means in the actual development of physics is that industrial needs determine the main directions in which physical research moves. The chief developments in physics have been in electricity, in connection with electric power production and transmission and in the use of light electricity in communications and in particular radio, and in metallurgy in connection with production and the uses of metal in engineering. On the chemical side development of course has been very largely in the direction of building up an independent heavy chemical industry. Now it may seem that those are purely practical ends and dispose of science in a purely practical way; but those of us who have studied science in this country know that it was exactly those kinds of requirements that gave direction to the great development of scientific discoveries that occurred in the seventeenth and eighteenth centuries. To come down from the general to a particular example:

Take a problem arising in the electrification of a country, the problem of power transmission. In power transmission what you really have to face when you go from the small distances in countries such as this to the enormous distances required in Russia is that losses which may appear quite trivial here, become overwhelmingly important there and that the causes of these losses of power must be searched out. That means among other things, a study of insulation in considerable detail. It was found, in fact, that extraordinarily little was known about the fundamental principles that determined the resistance of dielectrics to the high tensions. This leads right away from actual insulators to a study of insulating materials in their present state which is in effect a study of the passage of electricity through the crystals. Until this work was started in the Soviet Union this branch of crystal physics was extraordinarily little developed and the work of Joffé in the school of Leningrad has led to a clearer understanding of the various ways electrons are carried through metals. This solved, incident-

ally, the question of rectifying conduction of crystals underlying the crystal detector of the old radio days and the mechanism of various types of rectifiers of the copper oxide type. These fundamental researches go even further into the Quantum theory of the solid state. This was all knit together by men who had to be acquainted with the beginning and end of the process in theory and practice. The electrical engineers came to interest themselves in and to a very large extent understand the fundamental physical problems involved and the physicists went out into the field to see the problems the electrician had to deal with.

This is not an isolated example. The same kind of thing happened in the metal industry—with the problem of deformation and hardness. Most of our knowledge of metals, until very recently, was entirely empirical. The scientists could predict the properties of an alloy from their knowledge of others of similar type, but the physicists of the Soviet Union set out the more serious task of trying to understand the elementary mechanism by which a metal bends plastically (when it bends and does not straighten out again). This involved a great many discoveries of which the most fundamental was that the slip which occurs inside a metal crystal is not a phenomenon of slow movement but rather a series of sudden jerks, each like a little explosion. Thus the kind of curves of strength which an engineer gets, are really curves consisting of thousands of discontinuous jerks that no static theory can possibly account for. Only an atomic and breakdown theory holds for the plasticity of metals and all other materials. There is no static theory of deformation.

Another example from the same field is the problem of hardness. We are apt to think of all metals as having a certain inherent hardness.

Rehbinder, in the metal research institute in Moscow, has shown that hardness is an interface phenomenon, depending not only on the material but also very markedly on the medium with which it is in contact. This discovery that metals had different hardnesses in different media, such as oil and water, is of great theoretical importance and is practically useful for indicating which kind of medium is required for grinding and cutting metals in the most economical way.

These are examples to illustrate what I mean by this unity of Soviet physics, but there is much more behind it than that. It is impossible to understand the development of physical science in the Soviet Union unless we see that it is guided by far more general considerations. Science is conceived in the Soviet Union as an essential part of the general productive plan. The scientific worker comes in a very special place—the specific one of introducing new development and techniques, and the introduction of these new developments and techniques is itself a planned operation. The academic scientists in this country have often maintained that it is impossible to plan science, because science, by its very nature is the discovery of the unknown and if one knew what the unknown was one would not have to discover it, therefore it has to be left to pure chance and individual genius. Actually science is a human occupation like any other and if one observes what happens with new discoveries and how they are made, it will be found that although any individual discovery is due to a very odd combination of personalities and circumstances, the proportion of discoveries in any particular field is due to a proportionate employment of human effort, in hours and money, and that work in some fields of science is dropped or increased because of the change in focus of activities in those directions. A particular focus may be determined by secondary considerations, considerations of prestige, of intellectual interest, of advertisement value or patriotism. In that way a considerable body of people can be drawn into that field. There is no doubt that the enormous development of nuclear physics was due to the fact that it drew into its ranks the ablest of the young physicists and mathematicians of the times. Among many people who have distinguished themselves in nuclear physics are people doing things of vital importance in the war, but things in which nuclear physics have nothing to do. The progress of science depends on mobilising scientific workers and laboratory potential. In this way it is possible to plan science, not relying merely on individual discoveries, but on a proportion of discoveries certain to arise from work done in a certain field. In the Soviet Union the planning of science is part of the general industrial plan of the Union. Each group of scientists is connected with a specific industry, such as the metal industry. The plan for science is one not imposed on, but developed by the scientists. What is given to the scientists as a body are certain requirements of the general economy of the country. For instance, in the last Five-years' Plan there were ten big requirements put down for the scientists to tackle. They ranged from the more economic use of electricity, or of the discovery and expansion of new geological deposits to a study of the language and traditions of the various peoples of the Union. It was up to the scientists to find out how science would have to be developed internally to satisfy the general requirements and to push forward any new possible applications of science which seemed favourable. The plan for science is a plan made by the scientists; not by the Academy of Science, but

by every laboratory and by every group of workers in that laboratory, each laboratory settling their own problems, determining what their programme was and how it would fit in with the general scheme. That is how the Soviet Union has pushed ahead. It is all part of the practical application of dialectical materialism. It is impossible to discuss dialectical materialism here, it is enough to say that the general architecture of science and its activities are the real practical proof of the validity of the general views of dialectical materialism.

Now, with the war, the whole of Soviet Science has necessarily been given a new orientation. In the speeches of Soviet scientists at the beginning of the war and the articles that have appeared since there will be seen the war's problems—of the production and use of new weapons, the reorganisation of the country necessitated by the shifting of industry, the need to supply from new resources everything that had been lost in the first few months of the war. These are the primary jobs for the scientists to solve and the scientists are all working at them. They do not cease to work as physicists, chemists and biologists when working as socialists. Their task is determined by the situation, but it does not cease for that reason to be scientific. It is one of the tragedies of the present time that we lack full and practical contact with Soviet science. It is only when we have achieved this contact that we can realise in a rational way the possibilities of science for winning the war and building a new civilisation.

ELECTRIFICATION IN THE U.S.S.R.

By Hugh P. Vowles, M.I.Mech.E.

It has often been pointed out that Marxism is not a dogma but a guide to action. It cannot provide ready-made recipes to be applied to any and every circumstance without reflection. Thus in the revolutionary situation of 1917, Lenin and his associates were faced with problems of great complexity, differing in many ways from those visualised in the generalisations of Marx and Engels. Conditions in Russia before the Revolution had produced revolutionary classes, yet the country as a whole was still overwhelmingly a land of small-scale producers. Lenin himself drew attention to what he described as boundless areas over which semi-savagery and real savagery still reigned. With his genius for applying Marxist theory to a concrete situation, he seized on the fact that the Soviet Power would be menaced from within so long as small-scale production in Russia provided a surer basis for capitalism than for communism. But without electrification it would be impossible to build up large-scale industry. Hence Lenin's well-known saying that "Communism is the Soviet Power plus electrification."

In 1913 Russia had scarcely any electrical manufacturing industry worth mentioning. What there was of it was mainly the property of foreign capitalists, who held over 70 per cent. of the capital invested in electrical manufacturing plants, as well as half the capital invested in electric power stations. Most of the equipment was imported from abroad. A few steam turbo-generators had been imported and installed at St. Petersburg, Moscow and Baku, the largest of these being a unit of 5,000 k.w. There were no steam boiler manufacturing plants. Even in electric power production, where one expects to find the most advanced engineering practice, obsolescent fire-tube boilers operating at low pressures predominated. The bulk of the fuel supply was obtained from the Donetz basin without regard to potential resources widely distributed throughout the Empire. Fuel famines frequently occurred, during which coal was imported from Great Britain. Electrical transmission of power was only developed in one or two isolated districts over short distances. The maximum pressure was 22,000 volts as against contemporary American practice of 110,000 volts. Finally, in spite of Russia's unrivalled water-power resources, there was no hydro-electric development, with the exception of a few small plants in Transcaucasia and the Urals, the largest of which had an output of 1,350 k.w.

It must be added that the pre-revolutionary electrical equipment, such as it was, had been largely put out of action during the first world war and subsequent period of foreign armed intervention. In some districts it was completely destroyed. By 1920 electrical output as a whole had fallen to about one-quarter of its former low level.

It was at this stage, when the fires of civil war and foreign intervention were still raging that on Lenin's initiative the State Commission for the Electrification of Russia was established. The detailed plan was drawn up by a group of eminent Russian scientists, who realised that planned electrification would be impossible without overhauling, expanding and redistributing all branches of the national economy. Electric power equipment could not be produced on the requisite scale until a sufficient number of engineering factories had been established, workers trained, and the production and treatment of raw materials greatly developed.

It would take too long to tell in any detail of how well-nigh insuperable difficulties were overcome, and how scientific socialism in action led to the resounding triumph of planned electrification. The actual working out of the original plan, including the restoration of pre-war electric power economy, the extension and reconstruction of existing power stations, the building of large new

manufacturing plants, and the construction of 30 new power stations with a total capacity of 1,500,000 k.w., was completed in the minimum time scheduled, that is, ten years. In successive Five-Year Plans, initiated by Stalin, the original proposals have been far exceeded. The Soviet Union can now manufacture every type and size of electrical generating and distributing plant required. The manufacture of steam turbo-generator units has been standardised in sizes of 200,000 k.w. unit capacity down to 12,000 k.w. The largest hydro-electric generating units, those in hand for Kuibyshev, will have a capacity of 170,000 k.w. to 180,000 k.w. each. At the other end of the scale miniature plants operated by wind and water power are being intensively developed for installation in remote, sparsely inhabited regions.

The scale of development reached by 1939 may perhaps be best indicated by a few notes on the Volga power, transport and irrigation project, which includes the basins of the Volga and its main tributaries the Oka and Kama rivers. On completion, this project, with its dams, locks, canals, etc., will convert the Volga and its tributaries into a deep-water transport system, linking Moscow with the Baltic, White, Caspian and Black Seas. Three of the four main canals have been completed. Associated with the dams is a huge complex of hydro-electric power stations, including the Hydro-Centre at Kuibyshev, which alone will have a capacity of 3,400,000 k.w., by far the largest hydro-electric installation in the world. When I visited the Soviet Union in 1939, work was well in hand on this plant. Of other power stations for the project, a relatively small one of 30,000 k.w. and another of 100,000 k.w. capacity had been completed; one of 120,000 k.w. and another of 300,000 k.w. capacity were nearing completion, whilst work was also in hand on other stations varying in size from 150,000 k.w. to 400,000 k.w. capacity. The total planned capacity of the system is about 12,000,000 k.w. The whole of the work already completed or in hand has been undertaken since 1933. This may be compared with the Tennessee Valley Authority in the U.S.A., which in the same period has built power stations with a total generating capacity of about 350,000 k.w. Professor Luther Gulick recently gave the total capacity of T.V.A. as 1,000,000 k.w., but this is a little misleading, as some two-thirds of that capacity consists of old steam and hydro-electric stations built long before the Tennessee Valley Authority was established.

It may be noted that schemes similar to the Volga project have been worked out in detail for each of the great river basins east of the Urals. Irrigation is a prominent feature of such projects. Thus, the Volga project includes for the irrigation of an area about the size of Switzerland; a scheme so extensive that arrangements are included to prevent a serious lowering of the level of the Caspian Sea. This involves taking water from the River Don, and also from the rivers East Dvina and Petchora which flow northwards to the Arctic Ocean.

The United States still leads in *per capita* output of electricity. Nevertheless it can be shown that the Soviet Union already surpasses the United States in particular aspects of electrical development. Here I will confine myself to one feature in which the U.S.S.R. is already well ahead of the U.S.A. and all other capitalist countries. I refer to the development of heat-and-power stations. Many large Soviet cities of the U.S.S.R. are now equipped with extensive heat-supply networks as well as electrical networks, to which industrial, municipal and domestic consumers are connected. By the end of the Second Five-Year Plan the total capacity of such heat-and-power stations was 1,750,000 k.w. The supply to consumers of heat which would be wasted in other countries results in a much higher overall thermal efficiency in operation; an economy in fuel of some 30 per cent. being effected.

Apart from such special features, the correlated planning of generation and consumption of electricity necessarily holds much greater promise of scientific development and utilisation of resources than can be expected under competitive private enterprise. But the most important difference between capitalist and Soviet electrification lies in the divergent purposes which they are made to serve.

It is clear, and admitted by the Russians themselves, that electrical development under the Second Five-Year Plan was in some respects considerably behind that projected. Nevertheless Soviet electrification is planned, controlled and developed not for the benefit of professional investors, or political gangsters and grafters, but on behalf of every man, woman and child in the U.S.S.R. The successes far outweigh the mistakes. The result is manifested in the remarkable and continuous rise in the physical and cultural well-being of the mass of the Soviet people. Science has, in fact, been applied to the whole of Soviet electrification, including the social relations associated with it; not merely to its technological development. And since science, like peace, is indivisible, we may hope that in time other great peoples of the world will turn to the U.S.S.R. for lessons in social science in which planned electrification forms an indispensable element. When these lessons are learned and correctly applied to the special conditions prevailing in each country, then, and only then, will mankind as a whole be ready to pass from the realm of necessity into the realm of freedom.

GEOLOGY

IN SOVIET ECONOMY

By N. F. M. Henry

In 1931 Stalin said that as far as natural resources are concerned the U.S.S.R. is completely provided for. Yet in 1917 less than 1 per cent. of the country had been mapped even on a quarter-inch scale and only a very few of the useful elements were known to exist there and by no means all of these were exploited. Today the U.S.S.R. is a great modern industrial state standing up to the industrial output of the whole of Europe. It is clear that the geological sciences have played a great part in bringing about this high level of self sufficiency and I am going to discuss the attitude and approach of Soviet geologists to their problems, their organisation and the way in which they solved these problems.

In Tsarist Russia there were a few mineralogists and geologists of international fame such as Fedorov, Fersman, Vernadsky, Koksharov, Karpinsky, Obruchev, Tchernychev, Lõwinson-Lessing and Eremeyev. These scientists lived and worked in Petrograd and Moscow and small schools of younger people formed round them, but, owing to the general backwardness of the country, their influence was very limited. Throughout the rest of the vast Tsarist Empire science did not exist and in this respect Tsarist science was very like Tsarist industry. The Geological Committee had at its disposal personnel and funds which were totally inadequate to the task of mapping the country and by 1917 less than 1 per cent. of the territory had been mapped on a scale of inch to one mile. During the revolutionary period the number of geologists was reduced owing to the loss of men, such as the Finn Eskola, who were nationals of the border states.

From the very beginning, even in the middle of the civil war, the Soviet Government realised the fundamental importance of geology and paid special attention to it. Lenin said at this time that socialism meant the Soviet power plus electrification and this immediately raised the problems of coal and iron and other minerals. In 1920 Lenin sent three scientists, Gubkin, Lazarev and Archangelsky to Kursk to study the reason for the magnetic anomaly. The Kursk area was at this time actually a field of battle from which the Whites had not been driven, but in 1922 a great body of iron was discovered at a depth of 160 metres. During the civil war period, also, a special train was dispatched to Murmansk carrying with it a party of scientists, including Fersman. This railway had been built by the labour of prisoners of war in 1915–16 in order to bring supplies from Britain through the port of Murmansk and it passed through uninhabited country. The special commission had to decide whether it was possible to organise life there and to develop the economy of the Kola Peninsula region. The decision to start a series of intensive investigations was taken by the geologists and today on the site of one of their camps stands the new town of Kirovsk with over 40,000 people.

The task of organising geological work on an adequate scale was an enormous one. There were only a few geologists available for leading the work and for training the large number of students needed. At the same time new theoretical developments took place, because it was obviously impossible to proceed to survey the huge territories square by square as had been done over a period of 100 years in Britain. Time was a vital factor if the new state was to survive the period of intervention and the breathing space which succeeded it and which lasted only 20 years. During the period of the restoration of the national economy, from 1922 to 1927, many hundreds of students were trained in geological work and took part in the great exploratory expeditions to Kola, the Urals, Central Asia, etc. The study of the Kola Peninsula in the Arctic Regions is typical

of the work of these great expeditions, carried on year after year. At first the work was started in wild uninhabited country by a few men carrying packs on their backs. After two years there were whole parties, including engineers building roads, and still later there were scores of special research expeditions. The work was decisively stimulated by the discovery, in 1923–25, of vast apatite deposits. Large sums were allocated by the government and scientific research stations were built in the Khibine Mountains.

The needs of a rapidly developing socialist economy have hastened the sweeping away of obsolete divisions between sciences and have fostered the growth of a new, dynamically developing conception of nature as a whole. Historically, Mineralogy was the first of the geological sciences. It began in the modern world about 200 years ago and there have been chairs of Mineralogy at Oxford and Cambridge for over 100 years. During that period Crystallography developed as a body of techniques for the study of crystals, mainly minerals. Somewhat later, with the development of microscopical methods, Petrology emerged as a separate study. At the end of the last century Crystallography had ceased to develop and Mineralogy had become a purely descriptive study.

The evolution of X-ray techniques from 1912 onwards produced a tremendous development which led to the appearance of a new science of Crystal Chemistry which studies the laws of the orderly distribution of atoms in space and is of basic importance. When the results of this new study are linked with the great body of mineralogical and petrological knowledge, the new science of Geochemistry emerges. It is the study of the history of atoms in the earth's crust and of the processes by which minerals are made. It studies the distribution of the different elements in the different layers of the crust; the laws of migration, dispersion and accumulation of elements and of the formation of areas of concentration which provide the bases of our mining industries; also the participation of the elements in the soil and in living matter.

Soviet geochemists were able to indicate the best areas for mineral exploration, and step by step with this work the science of Geochemistry itself grew. It is no accident that Soviet scientists should lead the world in this new science, for its development was urgently required by their expanding economy.

By the beginning of the First Five-Year Plan, 1927–29, thousands of geologists were at work and the geological sciences had acquired high national importance and recognition both in the government and among the mass of the people. Considerable new funds were allocated and the economic development of the surveyed regions began. In Kola roads and railways were built for the new town of Kirovsk, the population of which grew in four years to 40,000. This town became the centre of the mining industry which now produces 2,000,000 tons yearly of fertiliser, plus important amounts of rare earths.

During the Five-Year Plans, in addition to the great growth of industry in the older regions of Moscow, Leningrad and the Donbas, economic development continued in the new areas surveyed be geologists. In the Urals, the Caucasus, Western Siberia, Central Asia, the Arctic Regions and the Far East enormous new industrial regions grew. In the North Urals the Solikamsk potassium deposits were discovered, completely dwarfing the famous Stassfurt deposits. In Bashkiria, between the Urals and the Volga lies the Second Baku, one of the world's major oil-fields discovered in 1930. The development of new industrial areas beyond the reach of the invader has been of vital importance to the military strength of the U.S.S.R. But such a process is also an essential part of the building of a socialist economy which can only be built on a firm alliance between the different peoples in the state, and this requires the rapid development of the natural resources of every part of the country.

After the Revolution the old Geological Committee took on a new lease of life. During the First Five-Year Plan it was completely reorganised as the Central Geological and Prospecting Institute for Scientific Research of the U.S.S.R. This Institute controls and plans the work of geological mapping, mineral prospecting, drilling for oil and the study of supplies of water, road metal, building stone, etc. The Central Institute has many affiliated institutes and stations in different parts of the country, from which thousands of geologists work. The more theoretical aspects of the work are studied by the Geological Departments of the Academy of Science, the Lomonossov Institute, the Petrographical Institute, etc. Technical applications are studied by the Institute of Applied Mineralogy. At first the work was developed round a few individuals and the organisation was very centralised. But in recent years, with the spread of scientific knowledge, decentralisation has been a very marked feature. All the above Institutes have numerous branches throughout the country. Scientific work as well as technical work is now done in the laboratories of large industrial associations and trusts. In some cases such as that of the Geological Bureau of the Apatite Trust, these bodies issue their own scientific publications. All these organisations work in conjunction and under the planned direction of the Academy of Science, which is responsible only to the Supreme Soviet.

In addition to the numerous geologists and mineralogists on the staffs of the Universities and the special Research Institutes of the Academy of Sciences, the Central Institute, which corresponds to our Geological Survey in Britain, has a permanent scientific and technical staff of 500. But in work under its control the number of scientists and technicians is about 10,000. In 1936 the total amount spent on this work was 1,000 million roubles (about £38,000,000), but in 1938 it was stated that this was to be increased. In Britain the number of geologists on the Geological Survey is about 60, but for comparison with the U.S.S.R. we can only take colonial territories. In India, for example, the total number of the entire staff of the Geological Survey numbers 35 and in the East and West African colonies about a dozen. The allocations of funds to these colonial surveys are microscopic and the difficulties put in their way by officialdom are often great. In the colonial territories there are a few score of geologists working for private firms, the greatest concentration of these being in the oil-fields. But no exchange of maps or information takes place between geologists of different combines and little of their work is made available to the official surveys. Firms are more interested in the exploitation of the richest and most profitable areas for a particular mineral and in the increase of monopoly control than in the rational development of each area.

The vital importance of geology in the U.S.S.R. is reflected in the great public interest in it. The Government has made strenuous efforts to popularise the science by means of press, platform and museum propaganda. The Lomonossov Institute runs special clubs for working people and organises popular education in science. Millions of school children study geology in the field and in the science laboratories of the Pioneer Palaces. The man in the street reads of the progress of geological theory and discovery in his daily paper and the leading geologists are public figures.

THE UNDERGROUND GASIFICATION OF COAL

By Harold Rose, B.Sc.

Tsarist Russia was a backward country. In spite of inexhaustible natural resources her industry remained undeveloped. The chemical industry was virtually non-existent. With the exception of the soda industry small scale enterprises were dependent upon imported raw materials, heavy chemicals and intermediates. Yet today the Soviet Union occupies one of the leading positions in the world in the chemical industry—an industry now based almost entirely on native raw materials.

It is particularly during the last ten years that such rapid strides have been made. Under the Five-Year Plans many new chemical works were constructed in the south, the central regions and the Urals and as a result the production of heavy chemicals has been increased to a considerable extent. The Soviet Union has established in recent years a plastic industry which is finding extensive application in aircraft production, and a synthetic rubber industry which now ranks as the largest in the world. Whereas previously all rubber was imported, it can now be stated that 80 per cent. of all the rubber required is now produced synthetically in Soviet plants. Under the Third Five-Year Plan the chemical industry is to be transformed into one of the leading branches of industry and is accordingly characterised as "The Plan of Chemistry." The production of sulphuric and nitric acids, synthetic ammonia, synthetic fibres, synthetic rubber and plastics is to be considerably increased. New works are to be established for the production of organic chemicals from the by-products of petroleum, synthetic rubber, coke-oven gas and natural gas. The construction is to be undertaken of sulphuric acid works utilising local pyrites and the waste gases derived from iron and steel works, power stations, synthetic rubber and tyre factories. Thirteen additional synthetic rubber plants and a number of factories for processing Soviet-grown natural rubber are to be put into operation in various parts of the country.

The responsibility for the rapid growth of the chemical industry rests largely on the numerous Research Institutes and Designing Institutes. Every branch of the chemical industry possesses its own Branch Research Institute whose function it is to develop new processes and to rationalise and improve existing ones. The Branch Institute develops a process from the laboratory scale to semi-scale and thence to the pilot plant. At this stage the corresponding Designing Institute is called in and plans are drawn up for the actual plant. This relationship in every branch of the industry ensures that the maximum benefit is derived from the research carried out and that all equipment and parts are standardised. The identity of interests between the chemist, chemical engineer and engineer breaks down the artificial barriers which unfortunately are only too prevalent in other countries.

The establishment and rapid growth of newly developed industries can be represented by two outstanding examples which will be discussed in more detail—the underground gasification of coal and the synthetic rubber industry.

It has long been the wish of scientists to devise a process whereby coal seams can be converted *in situ* into gaseous fuel, thus eliminating all underground mining operations. Modern practice presents a number of examples where minerals are brought to the surface without mining. Oil is an outstanding example. Salt is in many cases mined by sinking bore-holes and pumping water saturated with the salt to the surface. The extraction of sulphur by the Frasch process in Louisiana is carried out in a similar manner, using superheated steam. More recently it has been reported that the extraction of copper from pyrites by a process combining underground roasting and hydro-mechanical extraction of the ore has been accomplished in the Soviet Union.

The possibility of gasifying coal underground was first mentioned by the Russian chemist Mendeleev[1], who in 1888 wrote:

> "The time will probably come when even coal will not be extracted from the earth, but deep down in the earth the coal will be transformed into combustible gases and sent through pipes over long distances for distribution."

Somewhat later in England, William Ramsay drew up the first practical scheme and actually sank a shaft in the Durham coalfields, but his

experiments were abandoned. The Government and the industry were apathetic and no practical support was forthcoming. The attitude to Ramsay's suggestions at the time is clearly exemplified in a comment made by the President of the Institution of Mining Engineers in 1912:

> "There is a practical limit to the benefit that can be obtained by restrictive legislation, administrative and economic, which introduces new conditions that must be met by the application of new methods and appliances each introducing its own dangers . . ."

In 1913 some observations made in one or two technical journals attracted the attention of Lenin. With characteristic foresight he grasped the significance of the project and wrote an article for *Pravda*[2] outlining Ramsay's scheme, linking the problem of underground gasification with the main task of electrification.

> "The world-renowned English chemist," he wrote, "has invented a means of getting gas direct from the seam of coal *in situ* . . . one of the problems of modern technique is thus approaching solution . . . if this technical revolution took place, the cost of electrical energy would be reduced to one-fifth of its present cost. . . . An enormous amount of human labour that is now spent in extracting and distributing coal will be saved . . ."

The Soviet Union was the first country to take practical steps to develop the process. In 1931, on the initiative of Stalin, the Central Committee of the Communist Party adopted a resolution to undertake experiments. In 1933 Stalin advised Orjonikidze, People's Commissar of Heavy Industries, to enlarge the scope of the work and, as a result, a special organisation "Podzemgaz" was established for this purpose. Five experimental shafts were sunk in the Moscow, Donetz and Kuznetsk basins and in other parts of the country. On November 29th, 1933, the first gas was obtained from an underground generator at the Podzemgaz station set up in an anthracite colliery in Shakhty.[3] The other experimental shafts were then ignited and the first series of experiments were begun.

In 1936 the results that had already been established in the course of the preliminary investigation were summarised[4] and the main problems which were to be solved were defined as follows:

(1) The development of a process which would provide quantities of gas of constant composition.
(2) That provision be made for the control of the entire sequence of operations from the surface.
(3) That the reduction of preliminary mining operations be reduced to a minimum.
(4) That the construction of the underground gas producer be such as to maintain its general form regardless of the continuity of combustion

At the Chemical Engineering Congress held in London in 1936, N. F. Ushkevitch[5], the Soviet representative described the work of Podzemgaz and outlined the different methods that had been adopted for underground gasification. It is not without irony, that Ramsay's idea, neglected in his own country, should ultimately return as an accomplished fact.

In the first trials the coal seams were converted into a series of huge inter-connected gas producers, the coal being first broken up prior to ignition to reproduce the conditions which exist in the smaller gas producers normally used above ground. The coal was ignited by means of burning oil and timber and the fire maintained by a compressed air blast. The air was blown down and then along a horizontal shaft below the producers, rising upwards through the beds of burning coal, and the resulting gas delivered to the surface. An attempt was made to eliminate much of the labour involved in preparing the coal, by exploding the panel with dynamite, but this did not prove to be satisfactory.

This method was abandoned in favour of the "stream method," developed by the Donetz Coal Chemical Institute, by means of which the coal could be gasified whilst in the virgin state. Two steel-lined shafts were driven into the seam and connected below ground by a horizontal gallery where the combustion takes place. The coal is ignited electrically and the combustion maintained by an air blast which is pumped down one shaft, the gas issuing up the other. The calorific value of the gas could be increased by enriching the air blow with oxygen, which for the purpose of these tests was obtained from an adjacent chemical works, and its composition controlled from the surface, by regulating the air blow and the percentage of oxygen. It was further discovered that when the blow was discontinued for a time, the gas subsequently drawn off was unusually rich in hydrogen and could be used for a number of synthetic chemical processes.

The success of this method was attributed to the steep inclination of the seams in the Gorlovka (Donetz) field, which enables the fire to burn upwards and through to the surface. When applied to horizontal seams in the Kuznetsk basin, this method presented a number of difficulties, the most important of which was the tendency for the roof to cave in. The difficulty of maintaining uniform combustion across a horizontal seam was partially overcome by the "regenerative method," in which the air blow is alternated at half-hourly intervals with a steam blow in the opposite direction. The low calorific

gas produced during the air blow is sent through pipes to the consumer or may be used locally for firing boilers. The "water gas" produced during the steam blow, on account of its hydrogen content, provides the basis for the establishment of local chemical industries centred round the gas station, producing synthetic liquid fuel, synthetic ammonia, and from the latter nitric acid, fertilisers and other chemical products.

In 1937 the first experimental station operating on an industrial scale was opened at Gorlovka in the Donetz coalfields. Apart from the shafts and the exploration headings, no underground mining was involved. Considerable difficulty was experienced in establishing the cross connections between the shafts underground. It has been suggested that this was carried out by means of a specially devised water blast. This is not altogether surprising since reports from Sverdlovsk in 1937 indicated that experiments were being carried out with hydro-mechanical methods for cutting coal. The coal seam is cut by powerful jets of water operating at 15 tons pressure, and it is claimed that seven tons of coal can be cut in five minutes by this method. The water carries the coal underground along troughs, the large lumps being retained on screens and carried by a hoist to the surface, while the smaller pieces together with the water are carried away by suction pumps to settling tanks, where the water is drained off and re-used. This experimental station has supplied the solution to a number of technical problems and at the same time has provided the means of training new personnel in the design, construction and operation of the gas stations.

The first industrial station[6] in the world commenced operations in the Moscow coalfields in November, 1940, and since then several were built in the Donetz and Moscow basins and in Western Siberia. One industrial station in the Donbas was constructed in two sections, the one providing liquid fuel for a neighbouring chemical works, whilst the other produces the synthesis gas for chemical purposes. It is expected that this station alone will save the labour of some 800 workers, including 500 miners. Early in 1941 construction was commenced on a distinctly new type of station forming the basis of a new enterprise—the combination of a power station with a chemical works—based on the underground gasification process. Both power gas and synthesis gas will be produced, the former being used on the site for driving turbo-generators, instead of being piped to the consumer. It is estimated that this combine will save the labour of 2,000 workers, of whom 1,500 work underground.

The problem of eliminating the preliminary underground work was still to be solved and a considerable amount of development work has been instigated in recent years with this end in view. This has been achieved on an experimental scale by drilling into the seam a multiple system of inter-connected bore-holes. The gases from the burning coal are forced laterally through the incandescent seam from one bore-hole to others adjacent to it, after which the various flows are combined and the gas collected. It is considered that this method can be used to advantage for thick and porous seams, whereas the "stream method" is more suitable for thin, steeply inclined deposits having a thermally stable roof.

Important contributions are being made by the Research Institutes, which are not only providing solutions to the practical problems of immediate importance, but are also engaged on fundamental investigations into the thermo-dynamics of the gasification process. A study of the structure of the various coals used and measurements of the fusion points of their ash, has led to the solution of one of the major problems. Formerly, when the combustion was carried out at too high a temperature, the formation of clinker was a frequent cause of a choked fire-shaft. In addition, when combustion of a seam was nearing completion, mines frequently caved in, and subsidence of the surface was not uncommon. Gasification can now be controlled at temperatures just below the fusion point of the ash,[7] the latter forming a highly porous, but firm skeleton structure which provides the necessary reinforcement.

Lenin, in the article previously referred to, mentioned the use of special gas motors which could be fed with underground gas, for the generation of electric power. Although the idea of the gas turbine engine has engaged the minds of engineers for the last century, the rate of advance in its application has not been particularly rapid. The efficiency of such a turbine is considerably greater than the steam turbine and has the added advantage of not being dependent on any water supply. Largely on account of restriction on the working temperatures by the materials available for turbine blades and other parts exposed to the hot gases, the attainable thermal efficiency of the gas turbine has hitherto been restricted. It has recently been reported that this problem has been solved by Professor Makovsky at the Kharkov Mechanical Engineering Institute as a result of research on metals capable of withstanding the high temperatures. He has designed the first industrial gas turbine which is to be installed at one of the gas stations, and it may be anticipated that this innovation will rapidly displace the cumbersome and less efficient steam-raising boilers in which the power gas has been burnt in the past.

Another recent development of prime importance is concerned with the supply of abundant quantities of oxygen required for the enrichment

of the air blow. The production of liquid air, from which the oxygen is obtained, is normally carried out in high-pressure plants. This imposes a relatively heavy cost on the oxygen which in turn adversely affects the economic operation of the gasification process. As a result of Kapitza's[8] work on the low-temperature turbine for the production of liquid air, the Soviet Union will have available an abundant supply of oxygen at a fraction of the usual cost.

The realisation of the idea of underground gasification unfolds vast new prospects before Soviet economy. Whereas conventional mining methods will yield 60 per cent. of the total coal in the seam, underground gasification utilises from 80 to 90 per cent. of the coal. Thin seams of low quality coal which are normally considered unworkable for economic reasons, can now be exploited thus augmenting the existing fuel resources by millions of tons which would otherwise remain as dead ballast. Although the industry is still in its early infancy it has already been established that the cost of the fuel is reduced to one-third of its present cost, and that for the purpose of power production the capital cost of the plant is 30 to 40 per cent. below that of the usual type of generating station. Some idea of the increase in the productivity of labour can be gathered from the fact that one worker in a gas station produces as much energy in the form of gas as ten miners produce in the form of coal from the most highly mechanised colliery.

"We must put an end to our slow progress in the utilisation of gases; we must make wide use of natural and industrial gases and also develop the underground gasification of coal," said Molotov in his report at the Eighteenth Congress. "The wide transition to gasification in large cities will free us from such economic inefficiences as the long distance rail freightage of firewood." The Third Five-Year Plan incorporates a project for the construction of several new plants in the Donetz and Moscow coal fields, in the Urals, in Eastern Siberia, in Central Asia and in the Far East. The gas produced is to be used for the generation of power, for the chemical industry, and for municipal services.

During the present Plan, the underground gasification of coal is to be established as an independent branch of industry and heralds in a new stage in the development not only of mining technology but also of thermo-technique and power production. Serious consideration is being given to the possibilities of applying the technique to the direct reduction of iron ore underground without employing a blast-furnace and for the underground hydrogenation[9] of coal. In March 1941, just three months prior to the German attack, Soviet Engineers[10] were presenting a picture of the industry as it would appear within the next three to four years—a picture based not on random speculation but on the results of practical achievements in the past. Underground mining operations are to be eliminated entirely by the extension of the bore-hole system to all new stations. Each station will possess its own liquid air plant, compressors for the steam, air and oxygen blasts, turbo-generators and electrical distributors, plant for cooling and washing the gases, and a network of pipelines connecting the station to the consumer. With the application of automatic control, the gas station of the future will bear a greater resemblance to a modern power station than to a colliery.

> "Under socialism," said Lenin,[2] "the application of Ramsay's method through 'liberating' the labour of millions of miners, . . . will permit the reducing of working hours for everyone from eight hours, to say seven or even less . . . will render conditions of work more hygienic, will relieve millions of workers of smoke, dust and dirt, will speed up the conversion of filthy abhorrent workshops into clean light laboratories worthy of man."

ARTIFICIAL RUBBER PRODUCTION

By Harold Rose, B.Sc.

The strength of the Soviet fighting forces is sufficient evidence in itself that science in the U.S.S.R. has a capacity to meet the demands of total war. The co-ordinated industries, arising out of a planned economy, are able to utilise all the resources of scientific knowledge made available through the Academy of Sciences and the many Research Institutes. Among the many specific problems which confront these Institutes are those connected with the search for alternative sources of strategic raw materials in short supply. Rubber is one indispensable material without which modern war cannot be waged. The Soviet Union possesses no rubber plantations, yet in the course of a few years was able to build up a synthetic rubber industry which now probably ranks as the largest in the world. There were two reasons which brought this about. In the first place large quantities of rubber were originally required for civilian foot wear in order to release all available leather supplies for the rapidly growing Red Army. Secondly, the desire to become as far as possible independent of imported materials of strategic importance.

Since Goodyear in 1839 discovered the process of vulcanisation, converting the raw rubber into a product useful to man, considerable interest has been aroused regarding the composition of natural rubber. In their endeavour to elucidate the structure of the natural material chemists prepared the way for the production of synthetic products by bringing to light the fundamental compounds which could be converted into synthetic rubber-like polymers.

As early as 1826 Faraday demonstrated that rubber was essentially a hydrocarbon. Following on this Williams (1860) prepared a substance from rubber which he called Isoprene. Bouchardat (1875) converted isoprene to an elastic mass and postulated for the first time the relation between this product and natural rubber. It was, however, Tilden (1884) who supplied the key to the problem by establishing the constitution of isoprene as 2.Methyl-butadiene. Thus a basis was formulated upon which all subsequent research was developed.

All research was centred on isoprene until 1900 when investigations took a new turn with the discovery of Kondakoff[11] that dimethyl butadiene could be converted into a spongy rubber-like mass. It was not, however, until 1910 that Lebedev[12] showed that the parent material, butadiene, could be polymerised to a synthetic rubber and furthermore that the nature of the resulting rubber was dependent upon substitution in the butadiene chain.

It is not within the scope of this paper to deal with the many valuable contributions made by workers in other countries, since much of this work has already been recorded elsewhere. Rather is it the intention to show how Soviet scientists created and established a Soviet rubber industry with a capacity sufficient to meet with most of her requirements.

The production of butadiene from ethyl alcohol by Lebedev in 1928 laid the foundation of the new industry. Lebedev in all made some notable contributions and published a number of papers on the chemistry of butadiene. He became eventually the pioneer of large scale production of synthetic rubber in the Soviet Union, and in 1930, as a result of his work, the first block of Soviet synthetic rubber was produced in a Leningrad factory with an initial output of 900 lbs. a day.

From this stage production expanded at a rapid pace, as the following figures will indicate:

1932	...	...	375 tons
1933	...	...	2,370 ,,
1934	...	...	11,000 ,,
1935	...	...	20,000 ,,

In 1935 the first factory for the manufacture of chloroprene rubber was laid down in Leningrad and by the end of that year four factories were already in operation. Tyres made from this rubber were giving satisfactory results on trial road runs up to 25,000 miles. The technique had so improved by 1935 that in the course of twelve months the yield of rubber in terms of pounds of rubber per pound of alcohol increased from 14.4 per cent. to 23.1 per cent.

For the first few years most of the alcohol was obtained from agricultural products,[13] particularly cereals, and first converted to butadiene, either by synthesis or by high temperature crack-

ing. The use of cereals was considered unduly expensive and so a changeover was made, using potatoes, which for every acre gave 3,500 lbs.of alcohol, whereas cereals as a rule gave not more than 260 lbs. The local produce was converted into starch in factories which were built on the collective farms, the by-products providing a valuable concentrated cattle feed.

In view of the low price of natural rubber, considerable scepticism has been expressed in other countries as to the practicability of producing a synthetic rubber on the commercial scale which can compete in price with the natural product. From the socialist point of view this problem presents no difficulty. In fact the Soviet press, in reply to comments from abroad, states categorically that the advantages of synthetic production are unquestionable, pointing out that whereas (in 1935) one acre of potatoes produces 660 pounds of rubber per annum, one acre of rubber trees produces 320 pounds, and that from the point of view of labour costs a worker in a synthetic plant produces 20 times as much rubber in a day as a native working in a rubber plantation. In addition, an important factor to be considered is the recovery of by-products, particularly ether and butyl alcohol, which contribute to the overall economy of synthetic plants.

The production of ethylene[14] as a raw material for the rubber industry has received serious attention in the U.S.S.R. Some work has been done in the production of ethylene from coke-oven gas, but the main source of supply is the gas obtained in the cracking of oil which may contain up to 30 per cent. ethylene. In 1935 the first plant for the production of ethylene from "cracker gas" was erected in Transcaucasia and the project was considered sufficiently promising to estimate that within the next few years an output of 50,000 tons of synthetic rubber per annum was possible from this one source alone.

The industry began to make rapid advances from 1936 as a result of the introduction of emulsion polymerisation. This method was improved until the polymerisation reaction, which normally took some months, could be accomplished in a few hours.

From 1936 on, attention was given to sodium polymerised butadiene rubber, a process which had been discovered and used in the last war, and considerable quantities of this type were soon being produced. As early as 1934 a method of reclaiming products from vulcanised synthetic rubber was announced and there are indications from the many published reports that the reclamation of sodium polymerised rubber is not only practicable but has been adopted in practice on a large scale.

The production of sufficient quantities of butadiene for the large scale production of rubber was still a major problem. In addition to alcohol, butadiene can be obtained from acetylene and also from petroleum. The cracking of petroleum yields little butadiene but this can be prepared from the secondary butyl alcohol produced. The initial starting point from which most of the synthetic rubber is obtained in the United States and Germany, is acetylene derived from oil wastes, but in more abundant quantities from calcium carbide. The carbide industry, unfortunately neglected in this country, has been the basis of the German synthetic rubber industry since 1935, but it is only in recent years that a carbide industry has been established in the Soviet Union.

Most of the work in this new field has been carried out by Favorsky[15] and his associates. Favorsky has made a detailed study of the properties of unsaturated hydrocarbons and was the first to prepare isoprene rubber from carbide. In 1940 it was announced that the first tyres were being made from this rubber. Since the production of carbide requires coal, lime and cheap electric power, all of which are available in abundance in the Soviet Union, it is not surprising that rapid developments are taking place in the establishment of carbide industries for the production of acetylene in localities where the raw materials are available.

Acetylene is the starting point not only for the production of chloroprene and butadiene rubbers but also for numerous primary and secondary raw materials for the plastics industry and in addition for the synthesis of acetic acid and acetone. The demand for increasing quantities of acetic acid for the rayon industry was in itself a stimulus to the expansion of the carbide industry. Vinyl resins obtained from acetylene find extensive application in the production of lacquers, safety glass interlayers, adhesives, flexible electrical insulation, acid resisting sheets and artificial leather, while the acrylic resins derived from the same source are widely used in aircraft for windows, cockpit covers, and gun turrets. Work on the numerous products derived from acetylene has been under way for some time. The semi-scale production of polymers of vinyl chloride commenced in 1935 and by 1937 developed into production of plastic materials on an industrial scale. By 1940 several plants were already in operation. Research and development on plastic materials from acetylene is being carried out by Pavlovitch[16] and his collaborators at the Plastics Department of the Mendeleeff Institute of Chemical Technology, Moscow, and also at the Central Research Institute of Leather Substitutes, Moscow. The importance of industrial products using acetylene as a base may be judged by the

fact that the chemistry of vinyl compounds has been set up as a distinct branch by Professor Nazarov at the Institute of Organic Chemistry.

It appears that the Soviet Union now employs as raw materials acetylene, alcohol and petroleum. As the second largest producer of petroleum in the world it may be anticipated that increasing quantities of rubber will be produced from this source. In addition her large untapped resources of natural gas suggest a possible source in the immediate future. At least three types of synthetic rubber are in production,[17] designated as Sovprene, which is a polymerised chloroprene analogous to the American Neoprene, SKA, which is emulsion polymerised, and SKB, which is sodium polymerised, comparable with the German Buna rubber. Sovprene was originally manufactured from by-products of the Caucasian Oil industry—there is a huge synthetic rubber plant at Erivan, the capital of Armenia—but is now prepared from coal. The Magnitogorsk Combine has its own synthetic rubber industry based on Kuznetsk coal. In the Far East the coal of Cheremkhovo in conjunction with large native deposits of rock salt and lime is the basis of an expanding chemical industry which includes a synthetic rubber plant providing part of the rubber required by the Far Eastern Armies. Besides the extensive application of the different types of rubber in the manufacture of industrial and consumer goods, they are being used to an increasingly greater extent for caterpillar treads on tractors and tanks and find a wide range of uses in the aircraft industry from self-sealing petrol tanks to tyres for undercarriages. A large works at Voronezh, together with others in the Urals, is to-day able to supply the Voronezh-Gorki-Chelyabinsk aircraft factories with a substantial part of their rubber requirements.

Although recent production figures of synthetic rubber are not available there is every indication that the Soviet industry is the largest in the world. Already in 1936, according to figures from Soviet sources, 53 per cent. of the total rubber consumed was synthetic. By 1940 this figure had increased to 80 per cent. The Third Five-Year Plan (1938–1942) contemplates the construction of an additional thirteen synthetic rubber plants, indicating that production at the present time is at a very high level.

No account of the rubber industry of the U.S.S.R. would be complete without some mention of the extensive cultivation of rubber-bearing plants in recent years.

The possibility of growing rubber plants has attracted some attention in other countries particularly in America. Accounts of the experiments initiated by Edison on the "Golden Rod" in 1930 and more recently by Ford on Brazilian Plants have been published. These experiments have not been entirely successful judging from the lack of industrial activity in this direction. It is not, however, generally known that the U.S.S.R. has for some time been engaged on the processing on an industrial scale of natural rubber from plants, which is in no way inferior to tropical varieties.

In order to release herself from dependence on rubber imports the Soviet Government set up the Katchukones (Rubber Plants) Trust in 1927 for the purpose of studying a variety of rubber-bearing plants and for investigating the possibilities of cultivating a number of them on a wide scale. For this purpose many indigenous plants as well as imported varieties, particularly from China and South America, were examined. The first plantings of Hevea latex and gutta-percha were carried out in Central Asia and Turkistan. In 1929 an interesting plant was discovered having a larval parasite which produced a cocoon of rubber-like substance. Apparently the local inhabitants used it as a chewing gum. In 1930 several types, including the Mexican guayule and hondrella, were planted in the Ukraine. The hondrella tubers alone were expected to yield something like 3,000 tons in the following year.

At a congress of rubber technologists in Moscow in 1931, the preliminary results were examined. It was decided to extend the areas under cultivation and to send out scientific expeditions to explore the possibilities of lesser known plants. In the same year the first factory was set up for processing the rubber obtained from the kendyr plant, which gave a yield of 3–4 per cent. of rubber, with an expected output of 2,500 tons per annum. The tau-sagyz plant, which first received attention in 1931, was found to thrive not only in its native region but in other parts of the country as well. Moreover it was found that the plant developed with even greater rapidity in the cultivated state than in the wild state, with a yield of 14–30 per cent. of rubber. The first factory for treating tau-sagyz was set up in Kara Tau in Central Asia. By 1932 no less than 150 species of rubber-bearing plants had been examined, of which some 80 looked sufficiently promising to warrant further investigation.

One of the most interesting plants, the koksagyz, a yellow shrub related to the dandelion family was discovered by a scientific expedition in 1931 in the undergrowths of the Tian-Shan Mountains.[18] Both its seed and roots produce a satisfactory latex. The Bolshevik Farm in the Sumy Region in the Ukraine was the first to cultivate this plant on a large scale and it soon became one of the most profitable sources of income to the collective farms. Despite the fact that under cultivation it required considerable care and attention, it is easily acclimatised and will grow in cultivated soils as well as in cultivated

swampy lowlands, and has penetrated the North-east, East, South and Central Regions of the U.S.S.R. and Byelo-Russia. In fact it has been found to flourish as far north as Archangel.

Constant study has been made of the variable factors which might influence the yield. The effect of specific fertilisers on the rate of accumulation of the rubber in the roots is receiving attention.[19] A number of valuable contributions have also been made in the study of the chemical composition of the natural rubber.[20] Experimental work in plant physiology, biochemistry and genetics is producing results which are of immediate importance. During the 1940 harvest in the Ukraine the yield of rubber-bearing seeds was increased from 9.3 to 24.1 kgs. per acre on one-year plantations. Research in selective breeding, led by the famous geneticist, Lysenko, has already increased the weight of the rubber-bearing root from 3–4 grams to 18–20 grams. In the last three years a new method has been adopted to extract the rubber from the plants. Previously the whole plant had to be crushed, since the rubber is present in the roots, whereas in the more recent method an incision is made in the root through which the latex exudes and collects on the surface. When this latex is removed the flow starts again and it has been found that this process can be repeated 8 to 10 times in one season. It has been estimated that the adoption of this technique has almost doubled the production.

The area under cultivation is increasing each year. In 1936 16,000 acres of kok-sagyz were planted and the first factory for the processing of the rubber was built in that year. In the following year this was increased to 65,500 acres. By 1939 the following plants had been cultivated: kok-sagyz, tau-sagyz, krim-sagyz, teke-sagyz, hondrella, the gutta-percha bearing beresklet, the Chinese eucomiya and the South American guayule. More recently cultivation has been extended to Kazakhstan and Central Asia, where 45,000 arces of kok-sagyz have been planted. Artificial irrigation in Kazakhstan has stimulated the yield so that in 1942 some 50,000 tons of gütta-percha and plant rubber will be produced from this one region. In all 625,000 acres of kok-sagyz alone are now under cultivation.

The foresight and scientific planning, characteristic of Soviet achievements in industry generally, is emphasized by the firm basis on which the synthetic rubber industry has been established. Particularly in relation to the present struggle for freedom we have reason to be indebted to Soviet technology in a sphere of such considerable importance to the allied war effort.

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LOW TEMPERATURE RESEARCH AND DEVELOPMENT

By M. Ruhemann, Ph.D.

The building up of a Heavy Chemical Industry from scratch under conditions of socialism in a country with vast natural resources covering one-sixth of the earth's surface has made the Soviet Union, during the last fifteen years, one huge field of applied thermodynamics. Low Temperature research and development formed an integral part of the Five-Years Plans for the industrialisation of the country, its principal object being the rational and economic utilisation of the Soviet Union's gas resources. This involves the separation of natural and industrial gaseous mixtures, resulting in pure useful gases and in mixtures of a well-defined composition suitable for various industrial processes. Since all substances are completely miscible in the gas phase, the separation of gaseous mixtures necessitates the introduction of other phases that are not gaseous, and the most economical way of producing such phases is by liquefying at least a part of the initial mixtures. Since the critical temperatures of most of the components of gaseous mixtures lie below ambient temperatures, this liquefaction has to be carried out at low temperatures, thus requiring a specialised technique and refrigerating machinery.

The U.S.S.R. has very large natural gas wells as well as gas resources associated with mineral oils. Apart from methane as the main constituent, these gases contain varying amounts of ethane, propane and butane. Some of them, especially those heavily diluted with nitrogen, contain appreciable traces of helium.

The cracking of mineral oils and the hydrogenation of oil and coal yields annually billions of cubic feet of gas containing light paraffins and olefins as well as hydrogen. Of these the most important constituent is ethylene, which forms the basis for a number of chemical processes, notably for the manufacture of artificial rubber.

Still greater quantities of coke-oven-gas, a by-product of the metallurgical industries and containing mainly hydrogen, methane and carbon monoxide, but also several per cent. of ethylene, are produced in many parts of the U.S.S.R., only a relatively small portion being required to fire the coke ovens themselves.

Add to these gases atmospheric air as a source of oxygen, nitrogen and the rare gases and we can form an idea of the scope and possibilities opened up to scientists and engineers with no vested interests and obsolescent plant to consider, and with the financial backing of an all-embracing state organisation.

To sum up, the principal industrial products to be derived from low temperature gas separation are as follows:

From Air.

Oxygen for oxy-acetylene cutting and welding; "rich air", containing anything between 25 and 60 per cent. oxygen, for blast furnaces and gasification of coal, especially underground gasification;

Nitrogen for synthetic ammonia, and hence for fertilisers and explosives;

Argon, krypton and xenon for incandescent lamps and discharge lamps.

From Coke-oven Gas.

Hydrogen for hydrogenation and for the synthetic ammonia industry.

From Cracker Gases.

Ethylene for chemical synthesis, especially for the synthetic rubber industry.

Many secondary products can also be obtained in these processes, such as helium, methane, propane and butane, propylene, butenes, benzene, toluene, xylenes, etc.

The successful utilisation and co-ordination of existing resources required the closest co-operation of economists, scientists and engineers, which presupposes suitable organisational forms. During the period from the latter half of the First to the beginning of the Third Five-Years Plan, i.e., roughly from 1930 to 1938, the whole field was organised by the People's Commissariat of Heavy Industry. This comprised several "sectors" or "glavs" responsible for various fields of industry. Those which concern us here are *Glav Gaz*, concerned mainly with natural gas resources, *Glav Azot*, responsible for the synthetic ammonia and fixed nitrogen industry, and *Glav Nepht*, concerned with mineral oils and their by-products. Each of these Glavs controlled State Trusts which

dealt with the actual production of plant and products and which themselves controlled numerous works and factories. The Commissariat as a whole, as well as every Glav and Trust and almost every factory, directed research institutions and laboratories with varying degrees of specialisation. An important feature of this system of organisation was the State Designing Institute or *Gipro*, as it is called, attached to each Glav. These institutes, employing mainly engineers and draughtsmen, formed a valuable link between the research scientists and engineers and the actual production process.

Thus to take an example, the principal scientific research connected with the synthetic ammonia industry was conducted, on the synthesis side, by the State Nitrogen Institute of the Nitrogen Trust at Moscow and, on the low temperature side, for the production of hydrogen and nitrogen for the synthesis, by the Physico-technical Institute of the Commissariat of Heavy Industry and its Low Temperature Research Station at Kharkov. The designing of the plant was in the hands of Giproazot and Giproazot Mash, and the plant was actually built by the works of the Commissariat of Heavy Industry, notably the copper works at Tambov and the compressor works at Moscow and Sumi.

The industrial separation of gases at low temperatures requires an intimate knowledge of the thermodynamic properties of the components of gaseous mixtures and their liquid-vapour equilibrium. Very briefly, the kind of questions arising are as follows:—

(*a*) How much heat must be withdrawn from a mixture in order to liquefy it? (This requires a knowledge of heat capacities and latent heats of mixtures).

(*b*) By what means can this heat be withdrawn? (involving questions of refrigeration by compression and expansion of gases and liquids and therefore the thermodynamic functions of gaseous refrigerants).

(*c*) How can this heat be transferred through the plant? (requiring data on heat transfer coefficients, film coefficients and viscosity.)

(*d*) What are the compositions of the liquid and gaseous fractions obtained at various pressures and temperatures? (involving much detailed research on phase-equilibrium at low temperatures).

Ten years ago very few of these questions could be answered, even for a few individual cases. The data was either not known or unpublished. None of the questions could be dealt with on broad lines for want of information. There could be no question at all of a general theory. Now, mainly as a result of efforts of Soviet scientists, we possess a wealth of extremely valuable data on gases and gaseous mixtures and their equilbria with liquids. Not only can existing industrial problems be solved, but, in the course of the last two years, Soviet scientists have for the first time caught up with engineering and industry in the sense that they have the data available for the next steps in industrial development. To one who has followed up this race between scientific research and industrial development in the U.S.S.R. for some years, and has had occasion to realise the enormous demands put on scientists from the practical side by the veritable break-neck speed at which industry advanced, presenting ever new problems for the scientists to solve, this is indeed a notable achievement.

Research in connection with the separation of gases is best illustrated with the help of one specific example. By treating this in considerable detail, it will become clear how the engineering problems demanded scientific research, how that research was carried out and how the results of that research can now be considered as a whole and practically self-contained contribution to scientific knowledge.

In taking the example of the separation of coke-oven gas for the production of a 3:1 mixture of hydrogen and nitrogen for ammonia synthesis, I have chosen one of the earliest schemes of Soviet industrialisation, which has in fact formed the basis of the whole of Soviet Low Temperature Construction up to the present day.

In 1931 the U.S.S.R. received from a German firm the largest coke-oven gas separating unit ever built, an aggregate for rather over one million cubic feet of coke-oven gas per hour. At that time the U.S.S.R. knew nothing about gas separation. At the same time the above-mentioned organisation called Gipro-azot was formed and the Kharkov Institute was asked to supply data for designing Soviet separating plant. By 1933 the German plant was running smoothly and the data was beginning to come in. By 1935 the first Soviet plant was designed and at the makers. By 1937 it was running and by 1938 there were at least three more plants of various kinds in the U.S.S.R. supplying mixtures of hydrogen and nitrogen to the ammonia industry. Today there is hardly a single problem connected with coke-oven gas that we have not the data to solve.

The production of hydrogen and nitrogen from coke-oven gas involves cooling the initial gas in stages, condensing out one component after another, until finally only hydrogen and nitrogen remain. The refrigerant used is liquid nitrogen from a separate air separating plant, which simultaneously brings the composition up to the stoichometric figure. In the course of this process four main liquid fractions are formed and re-evaporated, the ethylene fraction containing ethylene, ethane and methane, the methane fraction containing mainly methane, nitrogen and

carbon monoxide, and the CO fraction containing mainly carbon monoxide and nitrogen. The gases in contact with these fractions contain almost all the hydrogen, but some hydrogen dissolves in the liquid. Thus the main necessity was to know the composition of all these fractions as a function of temperature and pressure, and incidentally to ascertain how much hydrogen is lost by solution.

With this in view, the following gas-liquid equilibria have been extensively studied at the Kharkov Low Temperature Research Station and some other laboratories:—

Ethylene–methane and ethylene–ethane.
Methane–nitrogen and methane–carbon monoxide.
Ternary mixtures of hydrogen, nitrogen and methane.
Ternary mixtures of hydrogen, nitrogen and carbon monoxide.

Valuable papers on these systems have been published which have incidentally given most useful demonstrations of so-called regular and perfect solutions, as well as some that were neither regular nor perfect, and which can now be used as a basis for all industrial processes involving these mixtures.

The final step in the separation of coke-oven gas consists in scrubbing the carbon monoxide out with liquid nitrogen. This must be done very thoroughly as the presence of even small traces of carbon monoxide in the product poisons the catalysts in the subsequent synthesis of ammonia. A particular study of the theory and practice of scrubbing was therefore made at the Low Temperature Research Station, which has since been followed up by other work in other laboratories.

The use of liquid nitrogen as the main refrigerant in this process led to the study of the thermodynamic properties of nitrogen, as the result of which a new thermodynamic diagram of nitrogen was constructed, which is now in general use in America.

A difficulty encountered in the separation of coke-oven gas consists in the solidification of benzol, which is present in larger or smaller amounts in the initial gas, depending on the efficiency of the debenzoling plant at the coke oven. The benzol fraction contains benzene, toluene, meta-xylene, small traces of the other two xylenes and a residue of naphthalene. Technically the problem arises in the following form: "What compositions of benzol fraction are permissible if the fraction is to be cooled to −45° C. without solidification." A number of binary and ternary systems containing these components were investigated at the Research Station and the solidification curves determined. The principal ones were benzene–toluene–metaxylene and benzene–metaxylene–naphthalene. The eutectic lines were fixed and a solid model made of the ternary systems. In one of the latest Russian journals to reach these shores, B. M. Kravchenko, has made a first attack on the quaternary systems and it is to be hoped that, when he is able to take up this work again, a valuable contribution will result to this extremely difficult problem.

The flow of liquids and gases in the pipes of these intricate pieces of apparatus cannot be accurately gauged without a knowledge of the viscosities of the liquefied gases and their mixtures. Only some six years ago nothing at all was known of the viscosities of liquefied gases. Soviet scientists have now determined them, not only for most pure liquids at temperatures ranging from the melting point to the critical point, but also for a large number of mixtures, in some of which the relation between viscosity and composition was quite unexpected. The systems investigated are:—

Pure liquefied gases at all temperatures and pressures.

Oxygen, nitrogen, carbon monoxide, methane, ethylene, ethane, propylene.

Binary mixtures.

Ethylene–methane, methane–nitrogen, oxygen–nitrogen, carbon monoxide–nitrogen, propylene–ethane.

It is not incidental that these researches, intended primarily to supply data for designing separating plant, have in fact laid the basis for a theory of the liquid state. The scientists engaged in this work had this aim in mind. They consistently refused to treat the problems narrowly, merely determining values needed to meet some specific case. On the contrary, every experiment and every piece of apparatus was designed to furnish as much information as possible concerning the systems investigated and every effort was made to achieve scientific accuracy, whether or not this was required for the specific technical problem.

The experiments here referred to are all connected with what may be termed the "classical" process for separating coke-oven gas, in which the object is to obtain a mixture of hydrogen and nitrogen. But the Soviet scientists did not stop at this. Valuable work was also carried out with a view to obtaining other products not envisaged in the original process. Thus it could be shown experimentally, on a semi-technical scale, that it is possible to obtain technical hydrogen from coke-oven gas with a purity of more than 96 per cent. with the help of liquid nitrogen boiling under reduced pressure. Moreover the production of pure ethylene from coke-oven gas was shown to be technically and economically possible, although the ethylene content of the gas is only 3 per cent.

Today no development in any field of gas separation would be possible without a very serious study of the work of Soviet scientists.

THE GENETICS CONTROVERSY

By J. L. Fyfe

There is at the present time an urgent need for the greatest possible clarity about the controversy which has arisen in the U.S.S.R. on the subject of genetics. This need arises not only from the importance of Anglo-Soviet mutual understanding, but also because of the scientific importance of the advancement of biological science and technique which is foreshadowed by the controversy. While it is true that the rights and wrongs of the different sides of the controversy can only be correctly evaluated by experimental work, it is nevertheless an essential preliminary to get a clear picture of its origins and scope. What follows is intended as a contribution to this aspect of the problem.

If we divide up biological science in an academic, departmental fashion, it is difficult to see why Lysenko, a physiologist, should clash with the geneticists and why it should be mainly plant breeders who are interested in vernalization and the physiology of development. But when we think of science in relation to technical needs, the connection at once becomes obvious. Both of these different lines of work are concerned with the improvement of planting material, of "seed" in the agricultural sense. The work of the plant breeder has as its aim the *selection* of the desired type. The theoretical basis of this work is provided by genetics, with its fundamental assumption that something (now called the *genotype*, but referred to by Mendel merely as *characters*) is passed on from one generation to the next according to certain rules and remains unaffected by the environment it finds in the individual or by the external environment.

Vernalization, in the wide sense, aims at changing the nature of plants by physiological treatment of the planting material. It is the opposite of plant breeding as usually practised in the sense that it is designed to *produce* by treatment, not to select by testing, the desired type. Lysenko and his associates are in the process of working out a theoretical basis for this kind of work and in view of what has just been said, it is not surprising that they find the assumption of a constant genotype a hindrance in this task. The special importance of vernalization work in the U.S.S.R. is of course its speed as compared with plant breeding. The results of vernalization are obtained in the year of treatment, but it takes 10 to 15 years to produce a new variety on a field scale by the established methods of plant breeding. In 1931, Stalin said "We are 50 or 100 years behind the advanced countries. We must make good this distance in ten years. Either we do it, or they crush us." The Fascist attack started ten years later.

Let us now examine the inter-relations between "Lysenkoism" and genetics. First of all we must consider the development of the science of genetics. Haldane has summed up the dialectical development of a science in the epigram which says that we make rules (set up hypotheses, theories) and then proceed to break them. Genetics has already broken a good many of its basic rules. To take two instances: the assumption of random recombination of ganetes (the basis of the 3:1 ratio) is subject to so many exceptions that it can now only be considered as at best very approximately true; again, the rule that every cell of every individual of a given species has the same number of chromosomes is probably never true; it has served its purpose as a starting point and is still useful for teaching purposes, but beyond that it is obsolete.

Until the last year or two the fundamental assumption of genetics, the constant genotype, has not been essentially weakened by genetical investigations. Such changes as were known to occur in the genotype were regarded as accidental or due to forces acting on an atomic scale, e.g. ionizing radiations. These changes do not affect

the concept of a genotype unchanged either by its living environment or by the environment of the organism, except in so far as they acknowledge the effectiveness of relatively catastrophic forces. But in the body of research which has been concerned with spontaneous and induced mutations of chromosomes and genes we find hints that even this most fundamental assumption is beginning to crack. The clearest instance is provided by McClintock's work on broken chromosomes in which she has shown that a broken chromosome changes its properties when transferred from one generation to the next. But the chromosome is a part of the genotype and in this case therefore our original assumption about the constancy of the genotype has broken down.

Another aspect of the development of genetics which must be mentioned is its tendency to develop along highly theoretical lines, i.e., along lines of little interest to the practical breeder. To some extent this is no doubt due to the suitability for genetical research of the otherwise unimportant fly *Drosophila*, but it could easily be avoided by a better organization of genetics.

Turning now to Lysenko, we must first of all try to assess his ability as an experimenter. His work has become known in approximately the following order: first of all we heard of vernalization in the strict sense, i.e., a technique for making winter varieties of cereals flower and set seed when sown in the spring. Then vernalization in the broad sense of treatments which affect development was extended to other types of crops, including thermophilous crops. The theory of phasic development was set up and on the practical side it was claimed that yields could be increased by treatments of this type, which were put into practice on a large scale on collective farms in the U.S.S.R. Then we heard that Lysenko was not content to confine his attention to the treated generation but was considering the question of the inheritance of the changes he could produce in the nature of plants and was favouring Darwin's and Michurin's theories of inheritance as against the Mendelian. More recently his work on intravarietal crossing and on graft hybridization has come into the field of view. Intra-varietal crossing is a method of obtaining increased yields by encouraging crossing within the variety in crops in which such crossing hardly ever occurs normally. "Formal" genetics provides no satisfactory explanation of this increased yield or of graft hybridization.

The initial reaction of the majority of scientists to all these ideas has been the same, as far as I can judge it. It has been consistently hostile. But today vernalization of winter cereals is universally accepted and the only relic of the former hostile attitude is "we knew it all the time." The vernalization of the thermophilous crops presents greater technical difficulties, because it proceeds at temperatures which favour the growth of moulds and bacteria. But it has now been repeated outside the U.S.S.R. and it is clear that the previous failures to do so were due to shortcomings of technique. Lysenko's results in the other fields have not been checked adequately outside the U.S.S.R., but the theory of phasic development is rapidly gaining popularity as a useful way of analyzing development, especially for the use of plant breeders. If Lysenko had gone no further than this his name would be known to plant breeders and plant physiologists of all countries for these important contributions and the quality of his work would not be questioned. But he has not hesitated to attack the most fundamental principles of genetics.

Lysenko maintains that a plant does not hand on to its progeny merely an assortment of unchanged genes, unaffected by the conditions of life of the plant, but rather that the conditions of life of the plant all have their effect on the progeny. This seems to me to be the essential point of difference between Lysenko and the geneticists. We must note here that he is mainly concerned with characters of agricultural importance, i.e., precisely with the type of character about which plant breeders complain that they get little help from genetics; and not with the type of abnormality with which much work on the inheritance of acquired characters has dealt. In putting forward this theory, which he bases historically on Darwin and Michurin, he is extending his work on the physiology of the development of the individual to what may be called the physiology of the connection between generations, a connection which has a somewhat peculiar significance in the seed plants, in which the offspring starts its life nurtured by the parent. His attacks on the pure line concept and his insistence that hybridization by grafting is possible are corollaries, subsidiary to the basic theory.

As has already been said, the value of Lysenko's theories will have to be tested experimentally and in practical application. All we can do here is to consider how they agree or disagree with current ideas. It is obvious that they are in many respects in direct contradiction to genetics as taught to beginners. But I have already shewn that the same is true of genetics at the highest level so far reached. It is possible to go further and take a theoretical work like Darlington's "Evolution of Genetic Systems" and find in it a mechanism of heredity which does not conflict with Lysenko's ideas. I refer to Darlington's plasmagenes, which he considers as in chemical equilibrium in the integrated cell, as contrasted with the mechanical equilibrium of the genes. It is probable that this chemical equilibrium is affected by the external environment, as Darlington himself suggests in

connection with "Dauermodifikationen." It is also at least feasible that the plasmagenes can be transmitted by grafting. They therefore might provide a mechanism for what Lysenko terms the "training" of plants (controlling what they hand on to their progeny) and for graft hybridization, both of which are impossible according to "formal" genetics. I hope I have made it clear that genetics is now reaching the position where the fundamental concepts on which it is based have almost served their purpose and will soon become a hindrance. The significant point is that genetics itself is beginning to modify them in very much the same direction as Lysenko seeks to do, though he approaches it from an entirely different experimental starting point.

If we take a broad view of the present position of the developing biological sciences which bear on the problem of heredity, we see that they are approaching a point where they will meet, discarding some of their basic rules in the process. Incidentally, this will involve what may be termed a crisis in genetics. The study of plant viruses, started as a branch of pathology, is forcing us to the conclusion that viruses are more in the nature of "plant proteins out of place" and are closely related to the cytoplasmic determinants of heredity and to the genes (*cf.* Darlington, *loc. cit.* and Bawden's text-book). The study of the structure and chemistry of proteins is beginning to disclose the physical and chemical basis of this relationship. Inside genetics we find the conception of the genes as discrete and autonomous units severely modified, while Lysenko's plant physiological studies lead him to propose very similar modifications. Everything seems to point to the conclusion that we are now standing on the threshold of revolutionary advances, which will involve throwing off the fetters of obsolete theories. It is not out of place today to point out that one essential preliminary to this advance is the defeat of Fascism. If the Nazis had their way, genetics would be kept in the form most easily capable of distortion into racialism and it is a striking fact that since 1933 the "Herrenvolk" has rapidly lost the knack of doing outstanding genetical research. It is also essential to this advance that contributions from all sides and approaches be given serious and unprejudiced consideration. I earnestly hope that this rather sketchy contribution will in some small way help to secure such consideration for Lysenko's work. The crying need, however, is for careful experimental work to test his theories, for it would be just as foolish to set Lysenko up as an infallible prophet as to dismiss his work without serious consideration.

THE SCIENTIST IN SOVIET SOCIETY

By M. Ruhemann, Ph.D.

In discussing science and scientists in the Soviet Union, we have to distinguish between the benefits which the socialist community confers on scientists and, conversely, the benefits which scientists confer or ought to confer on the socialist community. We are sometimes inclined to take the latter for granted, illustrating the Soviet scientists' contribution to socialist construction with a few striking examples. Surely, we say, freed from the fetters of capitalism and the frustration inflicted by vested interests, the scientific worker, the driving force in developing the productive forces, can and must achieve wonders in working out new production processes, leading the way forward to a higher productivity of labour and the material and spiritual enrichment of the entire population.

Yet if we but take a glance at the majority of scientists in Britain and other capitalist countries, not excluding our humble selves, we must in all honesty own to certain misgivings as to whether we are really fitted to fulfil this task. Clearly our whole ideological and educational equipment is not such as to make us fit persons to play a leading part in revolutionising production processes. We may have plenty of enthusiasm, but few of us would know exactly how to begin. No one taught us at school or college how to set about a job of this nature.

It takes time, hard work and experience to make socialist scientists. And so it is not surprising that many hard and bitter conflicts had to be fought out before our Russian colleagues were able to repay in kind the gifts that they received from the socialist community.

We must note three periods in the development of the Soviet scientist. In the first, from immediately after the revolution until about the beginning of the First Five-Years Plan, existing scientists were, in the main, taken over by the new society as they were found, with all their limitations, professional bigotry, academic exclusiveness and all the faults of bourgeois upbringing. Some of them rallied splendidly to the new needs, others again failed completely to grasp what the Bolsheviks were driving at. A few understood quite well but simply refused to co-operate and preferred the inglorious security of readerships in foreign universities to the storms and passions of society in childbirth. In the second transitional period, under the famous slogan "Cadres decide everything," a very serious attempt was made to re-educate the older scientists. Under the guidance of the Party and the Government they were helped and encouraged to see a new purpose in their work and their lives, and at the same time to teach the new generation the knowledge they had themselves received. In this period a new generation of Soviet scientists was growing up, men and women straight from the bench and the fields, many steeled in the battles of the Civil War and the strenuous days of "War Communism." During the whole of this period a rift was still noticeable between the old and the new, those with scientific knowledge but with a bourgeois mentality and those with a socialist mentality but very little knowledge. There were difficulties and conflicts, perhaps a few tragedies. Not till fairly recent times did this rift disappear, did the re-educated merge with the newly educated, the few with the many. In a speech of Molotov's in 1938 the third period of Soviet scientists was inaugurated with the following remarkable passage:—

> "An army almost ten million strong of national Soviet intelligentsia, closely connected with the working class and peasantry, is working with active hands on all the fronts of socialist construction. This enormous cultural strength is one of the most important factors in fulfilling the Third Five Years' Plan . . . in the final victory of communism in its historic rivalry with capitalism."

In this army of what we should here call black-coated workers, the Soviet scientist is playing a leading part. It is significant that in the last few years, in those fields of industrial development which were forging ahead with the greatest rapidity, heavy chemical industry and metallurgy, the scientists have begun to catch up with industrial practice, have moved from the tail to the head and are now leading instead of being led. It is significant too that in quite recent newspapers received from the U.S.S.R. there are frequent references to scientists undertaking leading organisational work in re-modelling war industries, especially metallurgy. No less than six members of the Moscow Academy of Sciences are engaged in mobilising the resources of the Urals for the war industry. Many students are taking a leading part in organising output on new lines. The students of Tomsk have assembled a whole shop of an evacuated plant in their spare time. Hitherto the scientists have led in theory but lagged behind in practice. Now the unity of theory and practice has been achieved.

What are the main characteristics of the modern Soviet scientist as against the scientist of the former generation and the scientist of capitalist countries? I think there are three, each very closely connected with the others:—

1. Public spirit and conscious citizenship;
2. Capacity for leadership and organisation;
3. Firm roots in the population as a whole.

A number of social factors have produced these qualities in the new generation.

1. The recruitment of scientists from the whole population and not from a small middle-class minority not only leads to better scientists but brings forward men and women with their social roots in the workshops and the fields. Scientists are not merely interested in production in the abstract, they are interested in such and such a factory where their brothers and sisters are working, in such and such a collective farm where they have parents and friends. Every one of a group of fourth-year students to whom I lectured at Kharkov knew every single factory in this highly industrialised area, what it was producing, how it was fulfilling its plans, what difficulties were being encountered and so on. Not merely had they read the newspapers; they had close personal contacts with the works.

2. Most Soviet scientists live around their place of work, many in blocks of flats which form a part of the institutes and laboratories. They are in continual contact with all the varieties of personnel that make up the inmates of a Soviet Institution, far more variegated in view of the special circumstances than in our own country. For every 100 scientists in a large laboratory, there may be 300 technical assistants, mechanics, fitters, turners, glass blowers, joiners book-keepers, cashiers, store-keepers, canteen workers, charwomen, etc. Such a group of people, forming what the Soviet people call a collective, is like a little community of its own. It has problems which have to be solved and these problems are political problems and have to be solved in a political way. The scientists play their part in the politics of their institute. They are continually brought up against these problems. Circumstances force them to find the solutions. They learn to judge persons, to deal with their neighbours. They achieve political tact and insight.

3. Finally the Soviet scientist has to deal with something that is practically unknown to scientists in capitalist countries, and that is public opinion. Here few people bother about what scientists are doing. The scientist leads a secluded life away from the public eye. Not so in the U.S.S.R. The people of the Soviet Union have been taught to respect scientists, to understand the important rôle they have to fulfil, but at the same time they have learned to expect much of scientists. Scientists are well paid and have good conditions of work. They are secured these good conditions and high wages through the labour of Soviet citizens. Science is a capital investment on the part of the Soviet people. In this respect the Soviet people feel themselves as shareholders. They are intensely interested in how their investments are carrying on. In the U.S.S.R. the scientist is a public figure. What he says and does matters to hundreds of thousands of people.

All these factors help to make the Soviet scientist what he is. Yes, it is relatively easy for the new generation to become good Soviet citizens. All the more must we take off our hats to those members of the old guard—and there are not a few of them—who in spite of their bourgeois upbringing and former capitalist environment have proved themselves worthy Bolsheviks in the scientific field. In congratulating Professor Bach when he was awarded the Order of Lenin, the Academy of Sciencies paid him a tribute which was as just as it was genuine:—

> "All the activities of A. N. Bach," said the note, "may serve as an example of uninterrupted co-ordination of theoretical efforts with the subservience of science to the practical tasks of socialist construction."

The Cadres Policy of the C.P.S.U.(b) is a very real thing from the point of view of the young Soviet boy or girl entering into a scientific career. Those leaving secondary school for the Universities and technical colleges meet a varied assortment of comrades who have taken the more arduous path via the farms and factories and evening schools. Fellow Trade Unionists, as well as foremen and managers are quick to single out bright young people, sometimes suggesting and sometimes helping them into a scientific career.

Directors of factories will proudly state that so and so many of their former workers are now famous men of science, art and literature. Success in the "technical minimum" tests, organised by the Trade Unions in conjunction with lectures and classes for all technical personnel, prominence in the Stakhanov movement (the raising of labour productivity through ideas and inventions of the men on the job) and a variety of other causes have led people from the farm, factory and office desk to the university and the laboratory.

The university entrance examination, just as all Soviet examinations, is meant to help and not to hinder the candidates. A five-year course, the last year of which is mainly taken up with practical laboratory work, followed by the State "finals" leads immediately to a job as working scientist in a research or factory laboratory. Those with special aptitude and the desire for an academic career have the opportunity of being chosen as "aspirants" or favoured research students. This selection is not based alone on scientific ability. It takes into consideration character, good citizenship and general past record. The aspirant receives a high State stipend, considerably more than the student, and usually good living conditions in a flat or hostel connected with the lab. It is the job of professors and research directors to do all in their power to help the aspirants forward, to arrange for them to be given work which is not only useful from the point of view of the plan of the laboratory, but which is also calculated to benefit the aspirant and give him as much insight as possible into important scientific problems. The "aspirantura" leads directly to the exam for "candidate of science," which ensures a well-paid and important scientific job.

There are no temporary casual labourers among the Soviet scientists; no sitting about on insecure grants. Every job is a job on the staff, with a fixed salary and quick promotion. In my time the young scientist started with 450 Rbl. a month, the candidate of science with 600 Rbl. By now these salaries are almost certainly much higher. Even then it was a rare thing for a scientist to work for more than a year without a rise. Salaries were finely graded. Every piece of successful work, every achievement was promptly met with some monetary reward, even if small. A prompt recognition of achievement was part of the cadres policy. It showed the scientist that what he did mattered, that he was not being forgotten, that the authorities appreciated him. A short working day of six hours and ample holidays (six to eight weeks in the year) was considered the scientist's right and the best suited to scientific productivity. On the whole the scientific worker had every reason to be satisfied with the Party and the Government.

The last fifteen years of socialist construction in the U.S.S.R. can be likened only to periods of intense boom in capitalist countries, though even this comparison is weak. A new world was growing up and man was building it. Towns and villages, colossal steel works, vast chemical combines were appearing as from nowhere. The world was changing and men and women were changing with it.

In such periods there is little danger of the scientists being lost in abstract thought. The pulsating life around them, the enormous demands on everyone and at the same time the intense capacity for happiness and enjoyment inherent in an era with profound emotions kept everyone in touch with practical things. Only occasional guidance was needed "from above." I recollect a circular passed to all scientific workers of the Commissariat for Heavy Industry encouraging them to be on the look out for results, possibly even chance results, which might be of use in industrial practice. The circular contained a number of useful hints. The scientist was not to neglect any such discovery, it ran. He was not to be content merely with publishing it in a scientific periodical. He was to write it up also in "simple and comprehensible language" and send it to the appropriate authority. He was to name the industries in which he thought it could be applied. He was to press for its application, even to the extent of himself approaching the managers and engineers of the factories, and finally if it was applied he was to be present himself at the tests and to take an active part in them. Another example of the unity of theory and practice.

TO THE SCIENTISTS OF THE WORLD

The following appeal was adopted at a Meeting of Soviet scientists held in Moscow on Sunday, October 12th, 1941.

We appeal to scientists throughout the whole world to unite their forces against Hitlerism, the greatest enemy of culture and science. By participating in the war of our country against Fascism we are endeavouring not only to drive out the bestial invaders, but also to help in establishing a democratic life for all peoples and to help the science and culture now threatened by Fascism.

The menace of Fascism which hangs over the whole world seeks to destroy freedom, civilisation and all scientific progress. The Nazi vandals have closed down the centres of culture in the occupied countries; universities and schools have been closed in Belgium, Norway, Holland, Latvia, Lithuania, Poland, Yugoslavia, Greece and Czechoslovakia.

Fascist reaction has stifled scientific thought in France. Fascism has defiled science. In the place of the power of reason the Fascists have proclaimed the power of brute force, ignorance and base instincts. In place of biology, the majestic science of the laws of life, the Fascists have invented their inhuman racial theory designed to justify the domination of the whole world.

For the sciences which foster greater unity among peoples and better mutual understanding, such as geography, ethnography and history, Fascism has substituted its so-called ge-politics, with the sole aim of justifying Germany's right to predatory invasion and the enslavement of other peoples.

Humanism versus Barbarism

Fascism has replaced the Humanism which characterises the spiritual development of peoples by the creed of eternal war and progressive marasmus, depravity and the enthronement of darkest reaction and the mass murder of the weak, the old and the infirm. It is a deadly menace to the culture and science which are most dear and precious to us. In their common work for the conquest of nature, scientists throughout the world pay the greatest attention to the furtherance of the culture and welfare of the human race, whereas Fascism utilises the achievements of modern science and technology for destruction and extermination.

By their work in aero-dynamics, scientists have developed the mastery of the aeroplane which has given humanity the most powerful means of communication across oceans, deserts and vast areas of land. But scientists and engineers did not labour in order to place in the hands of Fascism the means of destroying the cultural treasures of London, Leningrad, Moscow, Belgrade and Rotterdam, weapons for the murder of peaceful populations.

What was for long a benefit to mankind has been turned into a deadly weapon. We scientists have the duty of avenging this abuse of our achievements, for which the Fascists bear the full moral responsibility. In the name of this duty we Soviet scientists will give all our knowledge and strength to achieve the speediest destruction of Hitler's hordes. We are convinced that this grim and difficult struggle of all the freedom-loving and progressive people of the world will achieve the destruction of Fascism. We must give all our knowledge and all our strength for victory in this most terrible war in history.

Science helps Build Soviet State

Our scientific work has always been closely related to the requirements of the people of our country, which coincide with the interests of all

humanity. Our scientists have always put their work at the nation's disposal to make available its immense natural resources and to develop its national economy. The scientific development of this economy has permitted the creation in twenty years of a large-scale industry, and a reorganised agriculture which have increased the standard of living of all the peoples of the Soviet Union.

Our country grew in strength through the collaboration of all the nationalities inhabiting the Soviet Union. By the laws of our Constitution all nationalities have equal rights and are equally respected as members of our large Soviet family. Our scientists study the history of all the peoples of the Soviet Union, study their folklore and enrich Russian national culture. This work has fostered the unity of our people and their mutual respect for each other's culture.

We Soviet scientists are convinced of the final victory over Fascism and its complete annihilation. We consider that the mutual understanding and respect of all nations, based on equality and independent culture of each country, is the basis for their collaboration.

Scientists Unite!

We appeal to the scientists of the world at a time when the Soviet people have to bear the brunt of Hitler's war machine, when our towns are being destroyed and our people subjected to plunder and torture, at a time when the existence and the liberty of the peoples of the Soviet Union, Great Britain and the U.S.A. are being fought for on our battlefields.

All those who are interested in culture and science must unite to prevent Hitler from destroying nations one by one. We are convinced that the united efforts of the peoples of the Soviet Union and all freedom-loving countries will prove strong enough to exterminate Fascism once and for all and to guarantee freedom and progress to the peoples of all nations.

Long live the democratic countries which have united in the struggle against Fascism!

Long live free science and the further development of all human culture!

RESOLUTION

PASSED UNANIMOUSLY AT THE EASTER SYMPOSIUM, 1942:

This meeting of British scientists, technicians and science teachers has heard and discussed accounts of the brilliant achievements of Soviet scientists and engineers in many branches of research, and the important role that science is playing in the life of the Soviet citizens. It notes the exemplary way in which Soviet Science is playing its part in marshalling all the vast material resources of the country in the heroic defence against the Fascist invaders. We send our warmest greetings to the men and women of Soviet science, fighting in the front line of the common struggle of all humanity against the Fascist destroyers of world culture and world science. We are confident that the rousing call sent by you to all scientists of the world will find a ready response in deeds as well as in words, rallying them to greater efforts in achieving speedy victory, and pledge ourselves to work for this aim.

SOVIET ACADEMY OF SCIENCES APPEAL

TO SCIENTISTS OF THE WORLD

The following appeal was issued by the General Meeting of the Academy of Sciences of the U.S.S.R., held in Sverdlovsk from May 4th to 8th.

In the days of the second world war, when Hitlerite Germany threatens humanity with mortal danger of enslavement and extinction, and civilisation with destruction, when the freedom-loving peoples are united in the struggle against Hitler and his predatory army, the Academy of Sciences of the U.S.S.R., which at its general meeting called for further mobilisation of all our country's scientific forces to assist the front, addresses scientists the whole world over.

Scientists have always been proud of the sacred traditions of beneficial research, of the heroic past of science. The German Fascists curse and besmear the science of yesterday and today. Science has grown up under the banner of liberty and democracy, and scientists of all countries are justly proud of their freedom-loving traditions. The Hitlerites have befouled these sacred traditions, outstripping in their vandalism the villainous crimes of the most unbridled, blackest reaction of the past.

Hitlerism means the death of science. Research develops under the banner of intellect, truth, and service to the great aims of the progress of humanity. The Fascists replace science by mysticism and the blood-thirsty ravings of Hitler, the most frantic reactionary of our time. They replace the noble service of science to humanity by a disgusting concoction of abominable false "racial theory," enjoining pogroms and the extermination of whole peoples.

Death Threat to Knowledge

Science serves progress, it leads humanity towards a better future. The German Fascists attempt with fire and sword to pull humanity back to the darkest and most sinister ages of its history, to orgies of cannibalism and barbarian customs and to mediaeval obscurantism.

The victory of Fascism in the present war would mean the victory of death, destruction, darkness and slavery. It would convert modern civilisation into bloodstained, charred ruins, and the population of the globe into slaves dying of the greatest hardships and bloody torture. But the Fascists will not win!

Formidable danger has united all the forces of democracy and progress. When the Fascists invaded our country the whole powerful Soviet people rose against them like one man. The armed forces of the Soviet Union, under the guidance of Stalin, dealt the gravest blows to the hordes of Hitlerism and seriously undermined Hitler's war machine.

The time has come when the joint active struggle of all freedom-loving peoples against Nazi Germany will wipe the brown pestilence of Fascism from the face of the earth.

We must Improve Arms

We, the Soviet scientists, give all our knowledge to the cause of the defeat of the Fascist hordes with the passion of fighters in a just cause. We are working indefatigably to design and improve arms which will destroy Hitlerism, and to utilise the inexhaustible resources of our motherland for the needs of war. This is our duty to our motherland and to world civilisation.

In these historic days, the scientists of the Soviet Union call upon the scientists of all countries to rally still more closely the ranks of the anti-Fascist front of freedom-loving peoples of the world and to exert every effort in the struggle against Hitlerism.

Scientists of BRITAIN! Your country, the country of Newton, Clerk Maxwell and Darwin, the birthplace of the technical revolution, has experienced the horrors of Fascist bombardment resulting in barbarous destruction and the death of thousands of peaceful residents. Your country is waging a stubborn struggle against Fascism, but the defeat of Hitlerism demands new efforts and the mobilisation of all the forces of the British people and its science.

We extend a fraternal hand to you, our dear comrades. Together we shall facilitate by every means the consolidation of the anti-Fascist front and help to equip the armies of our States with the most up-to-date armament, more powerful and effective than that of the enemy. By our self-sacrificing work we shall expedite victory over German Fascism. Everything for the front! Everything for victory! Let us henceforth devote all our activities to this task!

Scientists of AMERICA! Your country is the country of powerful technique. Russian scientists have always studied the work of American scientists with the greatest attention. In the years of the reconstruction of industry in the Soviet Union, our people studied American science and technique with still greater interest.

United Technical Might

We call upon you, scientists of the United States, our dear comrades, to strive with still greater persistence to merge all the efforts of your people in the struggle against Hitlerism, to mobilise science and technology for the victory of democracy over Nazi barbarism. Very much depends upon the work of scientists in the struggle which is now in progress.

Let us still more vigorously help to strengthen all the means for the annihilation of the enemy. The united technical might of the freedom-loving countries, combined with the military valour of our peoples, will ensure the defeat of Fascism in 1942.

Scientists of the SLAV COUNTRIES! The Slav genius has presented the world with hundreds of outstanding scientists. The Fascists want to exterminate our race, but this will never happen! The brave and noble spirit of the Slavs lives in the hearts of the guerillas of Serbia, Croatia, Poland, Bohemia, Byelorussia and the Ukraine. Be worthy of your heroic brothers! Devote your strength to the struggle against the ferocious enemy of the Slavs—Hitlerism and its clique!

Research Workers must Revolt

Scientists of the COUNTRIES OCCUPIED BY HITLER! The Nazi scoundrels destroy the national culture of your countries, close down the universities and scientific institutions, turn the intelligentsia into errand boys to serve the Nazi "intellectuals," or simply exterminate them. Dear comrades, devote all your forces to the struggle against the hated enemy, against the Hitlerite invaders! No honest scientist of German-occupied countries can or will work for Fascist Germany!

The day is not far distant when the peoples of France, Poland, Belgium, Holland, Greece, Czechoslovakia, Norway and other German-occupied countries will throw off the hateful Nazi yoke, and when the scientists of these countries will resume their activities in freedom for the benefit of the peoples. Let us hasten their coming of this day by all means accessible to science! Launch ruthless struggle against Hitlerism!

Scientists of GERMANY! Hitler has plunged your country into an abyss of death and disgrace. He has trampled down German science. The country where Kepler and Gauss, Leibniz and Hegel, Mayer and Helmholtz grew up, thought and fought, has been turned into a prison and graveyard of science.

German scientists! Join the ranks of fighters against Hitlerism, devote all your forces to the struggle against the Nazi regime! Assist the anti-Hitler army! The more destructive and formidable are its weapons, the sooner the German people will throw off the yoke of Nazi oppression and take its place in the family of peoples following the path of progress!

Scientists of ALL COUNTRIES! Dear comrades! Decisive battles against the common enemy are approaching. None of us can stand aside from the struggle against Hitlerism. Let the Nazi beast meet its doom, caught in pincers from all directions by the advancing armies of our peoples! Let the year 1942 be recorded in history as the year of the utter defeat of the Fascist armies! Let it be impressed for ever in the memory of grateful mankind!

The enemy's backbone is already broken. Victory is near at hand. But it will require further grim battles. Let us unite in struggle against the common foe! Let a single noble aim be cherished by us all. Scientists of the entire world, champions of truth and reason, let hatred for the butchers and will to victory multiply tenfold in the great common cause.

In the name of the bright ideals of science, in the name of the salvation of mankind, let us throw in the scale of the present struggle the whole might of advanced science and technique. Let us supply the anti-Fascist armies with new types of powerful destructive arms, mobilise new industrial raw materials and power resources for victory over the enemy! We shall continue still more persistently to expose and destroy Fascist pseudo-science and demagogy.

Direct all the efforts of world science to help the Red Army and the Anti-Fascist front! All the forces of science and progress into the offensive, into battle against Fascism! The doom of Fascism is inevitable. Victory will be ours!

On behalf of the General Meeting of the Academy of Sciences of the U.S.S.R.

Signed: President: V. L. KOMAROV. Members of the Presidium: BAIKOV, BARDIN, BRITSKE, VARGA, VOLGIN, VYSHINSKY, DERZHAVIN, JOFFE, LYSENKO, MITIN, OBRAZTSOV, OBRUCHEV, ORBELI, STEPANOV, FERSMAN, CHUDAKOV.

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